# Aiding Decision Making in Transition to Integrated Farming Systems in Small Watersheds in Northeast Thailand Through a Multi-Agent Systems Model

**J.S. Caldwell, Uchada Sukchan, Francois Bousquet, Christophe Le Page, Kenji Suzuki, Nongluck Suphanchaimat and Somsak Sukchan**

Japan International Research Center for Agricultural Sciences (JIRCAS) Thailand and Japan, International Training Center for Agricultural Development Thailand, CIRAD France, Khon Kaen University Thailand, Land development Department, Thailand

**Abstract**

Two MAS models for diversification were developed with farmers who grow rice in rainfed paddies and sugarcane in upland fields in mini-watersheds. The first model was based on choices in a research agenda setting process made by 39 farmers with farm ponds and fruit, vegetable, or cattle production. This model begins from farmer assessment of well-being, followed by assessment of capital and pond water. The model postulates that farmers will begin diversification by expansion of cattle raising. This model was based on four orientations of farmers: conventional (rice / sugarcane), vegetable / fruit, livestock, and integrated farming. A second model for farmers with a vegetable / fruit orientation was based on interactions with four wet season on-farm trial farmers in the integrated farming group. This model assessed which plots would be suitable for diversification based on toposequence and pond proximity; selected crops based on sugarcane price, base pond water need, and household funds for investment in technology to increase water availability; selected vegetables based on price and rainfall; and decided upon vegetable technology based on household funds for investment. Both models are written in Unified Modeling Language (UML), and will be used to explore potential aggregate effects of diversification options.

## Introduction

In Northeast Thailand, only 5% of agricultural land has large-scale irrigation (Limpinantana, 2001), and most farmers practice rainfed agriculture on gently undulating terrain forming mini-watersheds. In valley bottoms, farmers grow rice in rainfed paddies for subsistence. In uplands on each side of the paddies, farmers grow sugarcane and cassava as cash crops. These crops are well-suited to Northeast Thailand, which is characterized by sandy soils (80% of agricultural soils, Yuvaniyama, 2001) and sharply delineated wet and dry seasons. However, sugar cane is a high input crop, resulting in significant borrowing, and farmers must sell to local mills, so farmers lack economic independence. Farmers would like to increase their economic options in agriculture. Vegetables, fruit, and livestock are potential diversification options, but they require more water than sugarcane or cassava. Many farm ponds have been built in the past decade, but they are not well-utilized for diversification (Ando, 2003).

Water and markets have common resource characteristics. Within farms, pond water for diversification alternatives can compete with water needs for subsistence rice. Across farms, extensive pond water use by many farms may affect mini-watershed hydrology. Lacombe

(2003) found through simulation of hydrological effects in an MAS model that farm ponds would be less effective for early rice seeding if many farmers simultaneously decided to use pond water to seed early. Similarly, when many farmers decide to produce a new product to take advantage of a market opportunity, the result may be flooding of the market and less income for all farmers.

A multiagent systems (MAS) model can assist farmer decision making in two ways:
1. To anticipate likely negative aggregate effects of individual decisions;
2. Serve as a catalyst for farmer knowledge sharing, understanding of common resources, and more efficient organization.

To achieve these objectives, farmer decision-making must first be translated into a model that can be verified with farmers and then used by them. In this paper we report how we translated decision-making by farmers in on-farm research into an MAS model for diversification. Our overall objective is to provide farmers with a complementary tool to assess longer-term effects of new technical options tested in on-farm research.

**Site and Methods**

The site for development of these MAS models are two villages in *Tambon* (sub-district) Nong Saeng, *Ampoe* (district) Ban Haet, Khon Kaen Province, Thailand. From May to September 2003, an interdisciplinary team (livestock, vegetables, fruit, integrated farming, soil /water management, farm management) designed and carried out a research agenda setting process in the site. Sixty farms with farm ponds carrying out fruit, vegetable, or cattle production were identified from a survey of the 207 farm households in the site and invited to participate in the research agenda setting process (Sukchan et al., 2005). The process had two principal objectives: 1) identification of farmers' goals and research needs; 2) formation of farmer experimental groups (Ashby et al. 2002). The choices made by farmers in the research agenda setting process formed the basis for a first MAS model. This model was based on four orientations of farmers: conventional (rice and sugarcane only), vegetable / fruit, livestock, and integrated farming. This model was considered to be a metamodel that will encompass models for each orientation's decision-making.

On-farm experiments involving vegetable and fruit crops and monitoring of pond water use for vegetables, fruit, and rice began on four farms in the integrated farming group in May 2004. Interaction between researchers and farmers during the course of this on-farm experimentation formed the primary source of understanding of farmer decision-making used in a second MAS model.

Both models were written in Unified Modeling Language (UML) (Le Page and Bommel, 2005) in February 2005. Three types of UML were written:
1. Class diagram, indicating attributes and activities of agents and objects, and relationships among the agents and objects.
2. Decision tree, indicating criteria and results of farmer decisions.

3. Sequence diagram showing decisions by agents on objects projected over time.

**Results and Discussion**

The metamodel (fig. 1) begins from farmer assessment of well-being as a first condition for an orientation towards diversification, followed by assessment of capital and pond water available for diversification. The metamodel postulates that farmers will begin diversification by expansion of cattle raising. Integrated farming made up nearly 40% of the goals of the farmers in the research agenda setting process. However, nearly half of the farmers joined the livestock focus group (Sukchan, 2005). These two results showed that many farmers saw expansion of livestock as the entry point into integrated farming. Income from increased livestock production can enable the farmer to accumulate additional capital for expansion into fruits and vegetables.

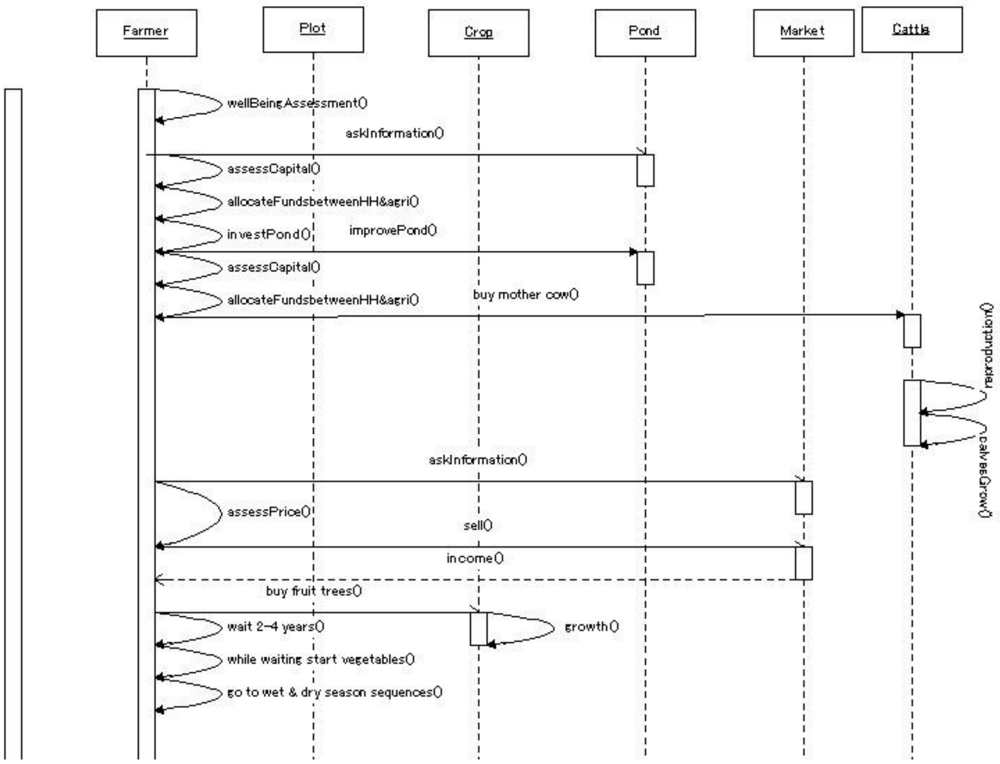


*Figure 1. Metamodel of farmer orientations leading to diversification.*

The second model for farmers with a vegetable/fruit orientation proceeds on a plot-by-plot basis to determine which plots could be used for vegetables. It has seven classes, divided into three types:

1. the <u>agents</u>: farmers
2. five <u>objects</u>, on which the agents act or from which the agents receive information and outputs: plot, crop, pond, cattle, and market.
3. the <u>clock</u>, which includes time as seasons and periods and rainfall.

The decision tree for the second model consists of nine submodels, five for the wet season and four for the dry season. The wet season decision tree proceeds as follows:

1. <u>Plot use decision</u>

The objects in this submodel are three kinds of plots: lower paddy (LP), upper paddy (UP), and upland (U) (fig. 2). Farmers decide on plot use based on toposequence and pond proximity. If the plot is LP and not high in the toposequence, farmers will plant rice; if it is high in the toposequence, they will plant sugarcane. If the plot is U and near a pond, farmers will consider diversification, but if the plot is far from the pond, they will plant sugarcane. If the plot is LP, they will also consider diversification.

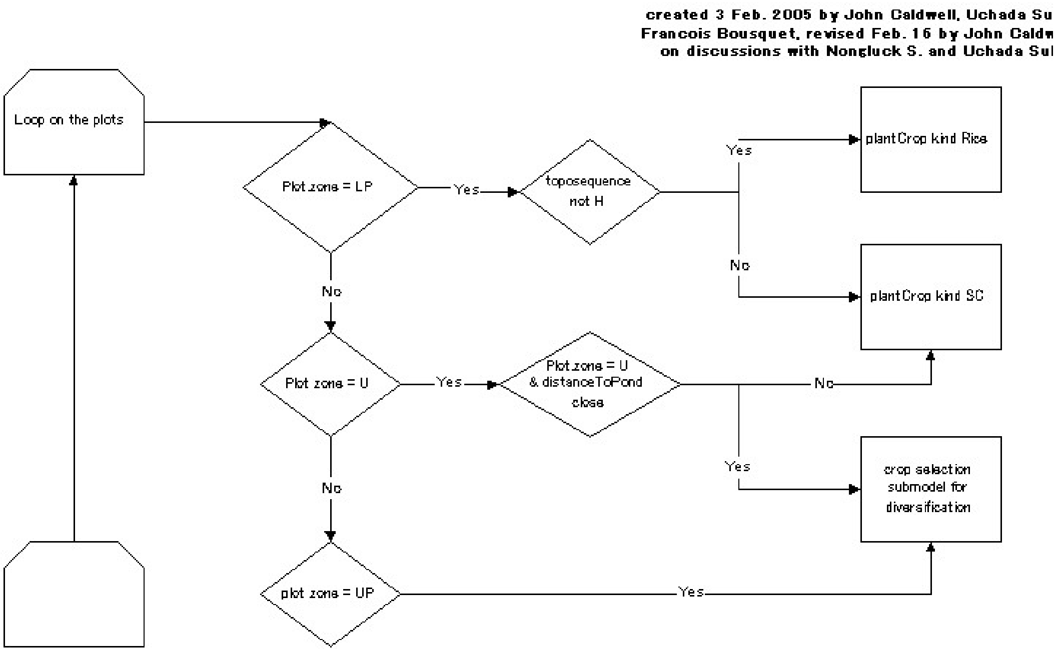


*Figure 2. Plot use decision submodel for wet season diversification.*

2. <u>Diversification decision</u>

The objects in this submodel are the plot selected for diversification in the previous step, the pond, and the market (fig. 3). Farmers make decisions to diversify into vegetables or not based sugarcane price, base pond water need, and household funds for investment. If sugarcane price is above 500 bahts, farmers will plant sugarcane and not diversify. If sugarcane price is below this threshold, they will assess the quantity of base pond water need, calculating the quantity of water needed for rice (seedbed, transplanting, emergency irrigation in dry spells) and livestock. If the pond has more water than the base pond water need, they will decide to diversify. If base pond water is inadequate, farmers will assess household funds available for investment to increase available pond water. If household funds are adequate, they will invest in water availability technology. If funds are inadequate, they will plant sugarcane in U plots and rice in UP if early rainfall is adequate, or leave the plot as fallow for cattle pasture if early rainfall is inadequate.

3) <u>Water technology decision</u>

The pond is the object of this submodel. Farmers choose based on preference between:

-- investment in the pond (build a new pond or enlarge an existing pond)

-- investment in groundwater (dig a deep well to add groundwater to pond rainwater).

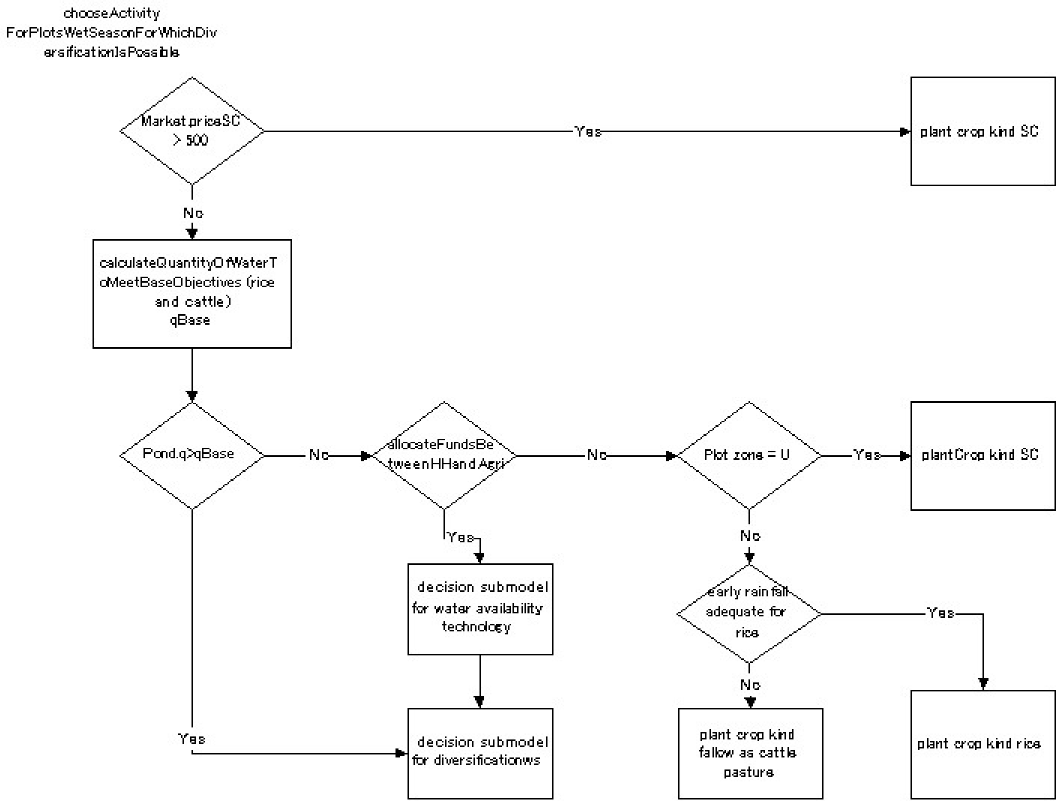


*Figure 3. Decision submodel for diversification.*

4) Vegetable crop decision

The objects in this submodel are the market, the plot, and crops (fig. 4). Farmers make decisions among three wet season crops based price, plot type, and rainfall. If tomato price exceeded 30 bahts / kg in the previous year's wet season, farmers will plant tomato; otherwise, they will plant *pakchi* (coriander) and onion. If *pakchi* and onion prices exceeded 10 bahts / kg in the previous year's wet season, they will plant these crops. In either case, they will also make a decision about wet season vegetable technology. If all prices are below the above thresholds, they will assess plot type and rainfall to decide among other crops. In upland fields, they will plant sugarcane. In upper paddy fields, if early rain is adequate, they will plant rice. If early rain is inadequate for rice, they will leave the plot fallow for cattle pasture.

5) Vegetable technology decision

The plot chosen for wet season vegetables is the object of this submodel. If farmers have adequate household funds to invest in a nethouse, they will build a nethouse. Otherwise, they will grow the crop without a nethouse.

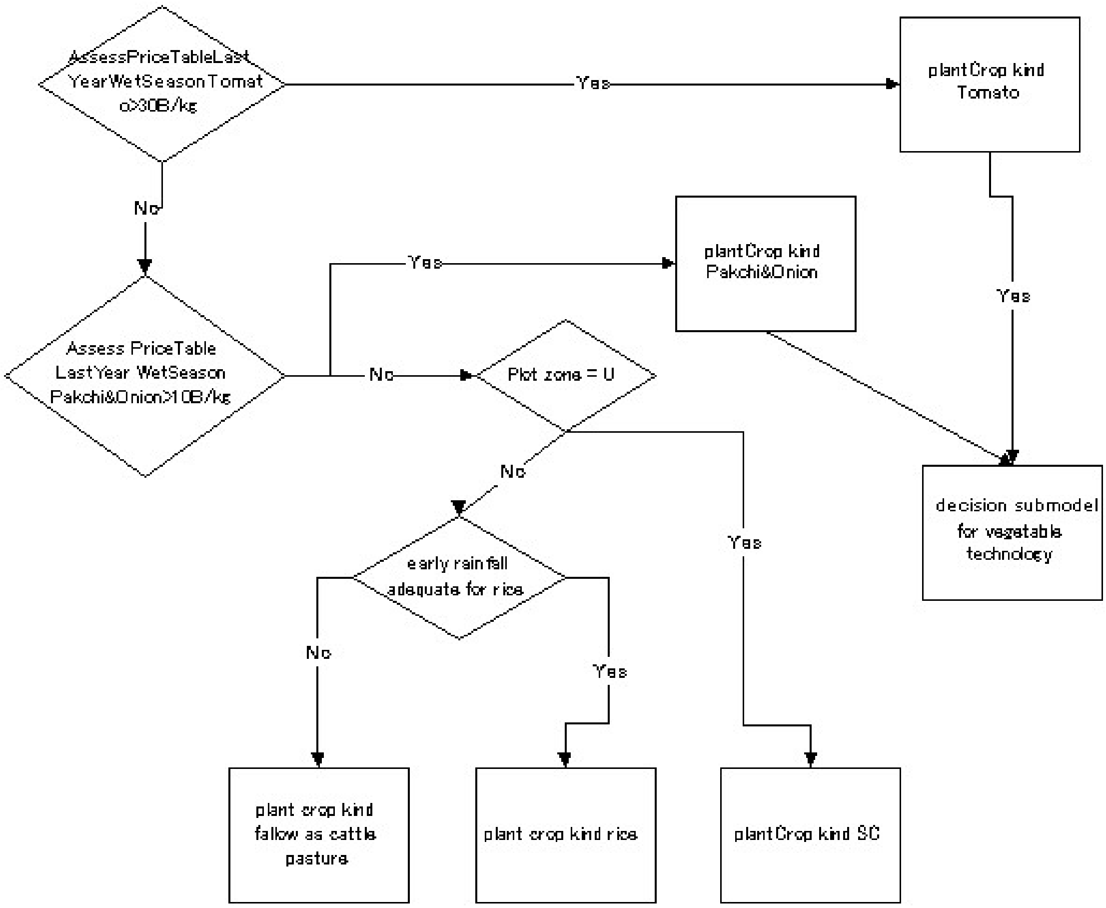


*Figure 4. Vegetable crop decision sub-model.*

## Conclusions and Next Steps

The two models have been developed as initial companion models in on-farm research. They have helped us identify key variables to monitor with farmers. The next steps in the process of building a more complete MAS model will be to verify and expand these two models. In particular, we need to obtain more information to include other vegetables, especially pepper, and labor and land factors. Then we will select a group of farmers selected from the three experimental groups, livestock, vegetables, and integrated farming. The experimental results from the three groups will be presented first. Then, each farmer will be given land in a mini-watershed in which hydrology effects have been modeled (Suzuki et al., 2005). Farmers will be given different areas of the three types of fields, numbers and sizes of ponds, and numbers of cattle, representing the range among the farms in the village. The game will be played over five years, the time span used in the 2003 goal-setting exercise. Rainfall will vary each year, and yield and prices will be based on data acquired from the on-farm trials.

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